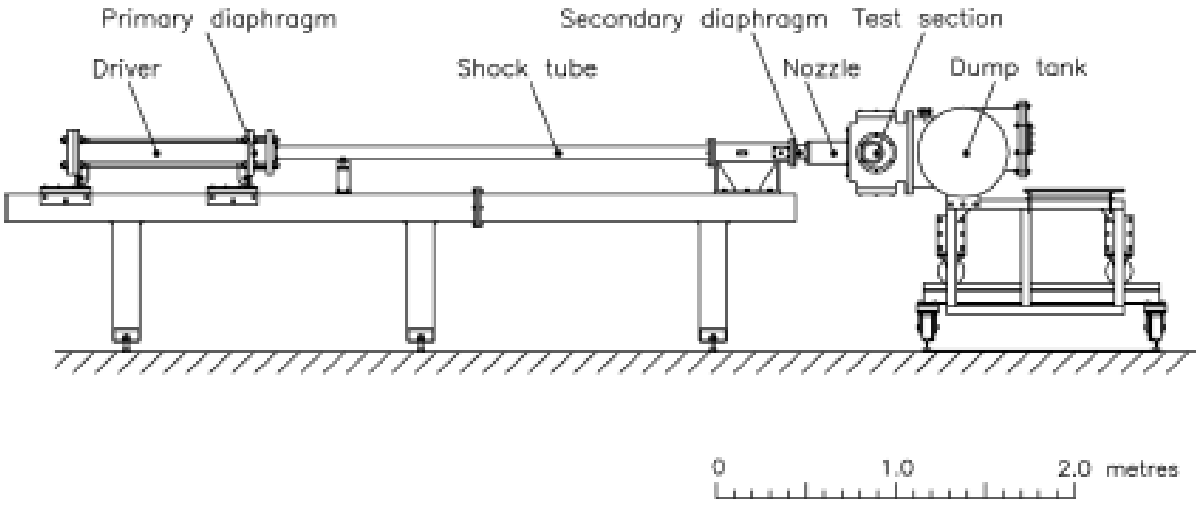
DRUMMOND SHOCK TUNNEL TRAINING PROGRAM



Trainee Name		Signed	
Supervisor Name		Signed	
Date of Commencement			
Training Level			

Competency Achieved	
Date of Completion	
Signed by Supervisor	
Signed by Trainee	

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Division of Mechanical Engineering Technical Officer

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Contents.

1. Training Outcomes for Trainees.

Compiled from the Operators Manual.

The Trainee must:

- Understand the Operation of the Drummond Shock Tunnel.
- Be able to identify the Drummond Shock Tunnel Components, their function and operation.
- Be able to locate safety equipment (WHS Induction by Supervisor)
- Be introduced to Drummond Shock Tunnel service and workshop personnel (WHS Induction by Supervisor).
- Be introduced to stock administrator (WHS Induction by Supervisor).
- Adhere to the hours of Operation.
- Be trained in the operating procedures of the Drummond Shock Tunnel.
- Be trained in the cutting of diaphragms.
- Be trained in the order process for consumables.
- Be fully supervised during the training program.
- Be trained in the operation of the diffusion pump system (optional).
- Be trained in the venting of explosive gases through the dump tank (optional).
- Be trained in the setup of the Drummond Shock Tunnel for different modes of operation (eg gas ratio's, gas type etc.)
- Be trained in the use and maintenance of pressurised equipment (WHS Internal Course)
- Be trained in the use storage, transportation of gases (Linde Gases Training Course)
- Be trained in the identification and use of pressure fittings (Swageloc Training Course)
- Achieve competency before independent operation of the Drummond Shock Tunnel.

2. Training Outcomes for Supervisors.

The Supervisor must:

- Understand the Operation of the Drummond Shock Tunnel.
- Be able to identify the Drummond Shock Tunnel Components, their function and operation.
- Be trained in the operating procedures of the Drummond Shock Tunnel.
- Adhere to the hours of Operation.
- Have completed all Workplace Health and Safety Inductions.
- Be competent in training others in the cutting of steel diaphragms.
- Be competent in training others in the order process for consumables.
- Be fully supervised during the supervisors training program.
- Be competent in training others in the operation of the diffusion pump system.
- Be competent in training others in the venting of explosive gases through the dump tank.
- Be competent in training others in the setup of the Drummond Shock Tunnel for different modes of operation (eg gas ratio's, gas type etc.)
- Be trained in the use and maintenance of pressurised equipment (WHS Internal Course)
- Be trained in the use storage, transportation of gases (Linde Gases Training Course)
- Be trained in the identification and use of pressure fittings (Swageloc Training Course)
- Be trained in supervision of staff (UQ internal course)
- Achieve competency before independent supervision of the Drummond Shock Tunnel operation.
- Achieve competency before independent training of the Drummond Shock Tunnel operators.

3. Operator Training Record[1].

Description	C	NYC
Demonstrate knowledge of the Operation of the Drummond Shock Tunnel. • Uses correct terminology • Correctly describes theory and operational details • Correctly identifies components of the Drummond Shock Tunnel • Correctly identifies the operating parameters and purpose of each component		
Be able to locate safety equipment. • Undertaken Divisional Safety Induction • Undertaken Area Safety Induction • Completed Safety Declaration and Induction Form		
Be introduced to Drummond Shock Tunnel service and workshop personnel. • Identify the Technical Staff • Completed Safety Declaration and Induction Form		
Be introduced to stock administrator. • Identify the Administrative Staff • Completed Safety Declaration and Induction Form		
Adhere to the hours of Operation. • Understands hours of Shock Tunnel Operation		
Demonstrate knowledge of the operating procedures of the Drummond Shock Tunnel. • Able to explain Operating Procedures • Able to explain Safety Requirements • Able to Start up System • Able to Evacuate System • Able to fill Shock Tube • Able to fill Reservoir • Able to Launch System • Able to Vent System • Able to Turnaround System • Able to Shutdown System • Able to Abort Sequence • Able to undertake all Operations in a Safe Manner Attach Reference details of all Launches undertaken during training		
Demonstrate knowledge of the cutting of steel diaphragms. • Undertake TSU training in the use of Guillotines. • Able to correctly identify safe operating procedures for Guillotines • Complete course to a suitable standard		
Demonstrate knowledge of the order process for consumables. • Able complete Paperwork correctly • Able to maintain gas supplies to correct Stock Levels • Able to correctly identify Consumables and relevant Part No.		
Demonstrate knowledge of the setup of the Drummond Shock Tunnel for different modes of operation • Able to mix gases to correct ratio in the relevant Tube or Reservoir		

[1] Referred to as trainee

• Able to setup different operating pressures in the relevant Tube or Reservoir • Able to fill at low Nozzle Supply Pressure		
Demonstrate knowledge of the use and maintenance of pressurised equipment • Undertake WHS Pressurised Equipment Training Course • Able to correctly identify safe operating procedures for Pressurised Equipment • Complete course to a suitable standard		
Demonstrate knowledge of the use storage, transportation of gases • Undertake Linde Gases Training Course • Complete course to a suitable standard		
Demonstrate knowledge of the identification and use of pressure fittings • Undertake Swagloc Training Course • Complete course to a suitable standard		
Demonstrate knowledge of the identification and use of Vacuum Gauges • Able to undertake Leak Detection • Able to fill out Preliminary and Service Leak Test Reports correctly • Complete course to a suitable standard		

Note:

Supply all supporting certificates, documentation, calculations and notes with the Training Record as evidence of competency.

4. Supervisor Training Plan.

Description	C	NYC
• Demonstrate knowledge of the Operation of the Drummond Shock Tunnel. • Uses correct terminology (Advanced knowledge) • Correctly describes theory and operational details (Advanced knowledge) • Correctly identifies components of the Drummond Shock Tunnel (Advanced knowledge) • Correctly identifies the operating parameters and purpose of each component in detail (Advanced knowledge)		
Introduction to the location of safety equipment. • Able to organise Divisional Safety Induction of trainee if required • Able to undertake Area Safety Induction of trainee • Able to complete Safety Declaration and Induction Form with trainee		
Introduction of Drummond Shock Tunnel service and workshop personnel. • Able to complete Safety Declaration and Induction Form with trainee		
Introduction of trainee to stock administrator. • Able to complete Safety Declaration and Induction Form with trainee		
Adhere to the hours of Operation. • Able to explain hours of Shock Tunnel Operation to trainee		
Demonstrate knowledge of the operating procedures of the Drummond Shock Tunnel. • Able to explain Operating Procedures to a trainee • Able to explain Safety Requirements to a trainee • Able to demonstrate System Start-up to a trainee • Able to demonstrate System Evacuation to a trainee • Able to demonstrate Shock Tube filling to a trainee • Able to demonstrate Reservoir filling to a trainee • Able to demonstrate System Launch to a trainee • Able to demonstrate System Venting to a trainee • Able to demonstrate System Turnaround to a trainee • Able to demonstrate System Shutdown to a trainee • Able to demonstrate System Abort Sequence to a trainee • Able to demonstrate System Shutdown to a trainee • Able to demonstrate Safe System Operations to a trainee Attach Reference details of all Launches undertaken during training		
Demonstrate advanced knowledge of the cutting of diaphragms. • Organise TSU training in the use of Guillotines for trainee • Able to correctly identify safe operating procedures for Guillotines to trainee • Complete course to a suitable standard		
Demonstrate advanced knowledge of the order process for consumables. • Able to demonstrate Correct Paperwork completion to trainee • Able to demonstrate correct Stock Levels of Gas Supplies • Able to demonstrate correct identification of Consumables and		

relevant Part No's to trainee		
Demonstrate advanced knowledge of the operation of the diffusion pump system. • Able to demonstrate diffusion pump Set-up to trainee • Able to demonstrate changing the diffusion pump oil to trainee		
Demonstrate advanced knowledge of the setup of the Drummond Shock Tunnel for different modes of operation • Able to demonstrate the mixing of gases to correct ratio in the relevant Tube or Reservoir to trainee • Able to demonstrate the setup of different operating pressures in the relevant Tube or Reservoir to trainee • Able to demonstrate the filling of a Low Pressure Nozzle Supply to trainee		
Demonstrate advanced knowledge of the use and maintenance of pressurised equipment • Undertake advanced WHS Pressurised Equipment Training Course • Able to demonstrate the identification of safe operating procedures for Pressurised Equipment to trainee • Complete course to a suitable standard		
Demonstrate advanced knowledge of the use storage, transportation of gases • Undertake advanced Linde Gases Training Course • Able to demonstrate the safe use, storage and transportation of gases to trainee • Complete course to a suitable standard		
Demonstrate knowledge of the identification and use of pressure fittings • Undertake advanced Swagloc Training Course • Able to demonstrate the identification and use of pressure fittings to trainee • Complete course to a suitable standard		
Demonstrate advanced knowledge of the identification and use of Vacuum Gauges • Able to undertake Leak Detection • Able to fill out Preliminary and Service Leak Test Reports correctly • Complete course to a suitable standard		

Note:

Supply all supporting certificates, documentation, calculations and notes with the Supervisor Training Record as evidence of competency.

1 Introduction

The Small Shock Tunnel or ”Drummond Tunnel” was originally manufactured by the Department of Defence and used to study chemical reactions of shock-heated gas [1]. The name ”Drummond Tunnel” comes from the name of one of the investigators who was responsible for building the original tunnel. However, the tunnel as it stands today, some 30 years later, (see *Figure 1*) is quite different to its original configuration.

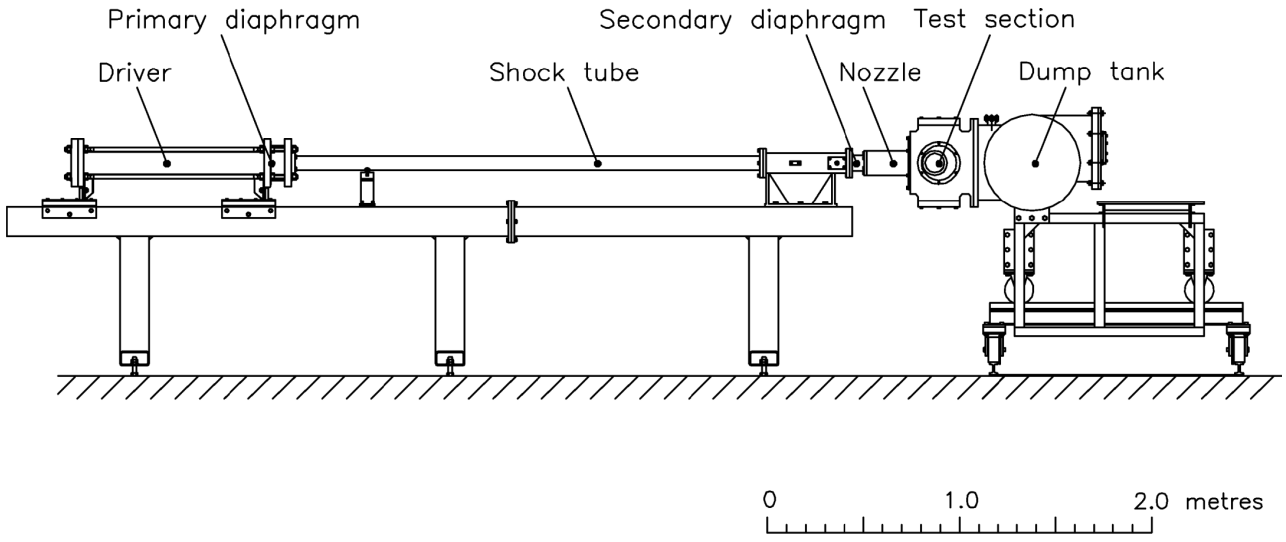

Figure 1: Layout of the Drummond Tunnel as of September 2006

Recent modifications to the tunnel [2] added a new test section with optical access, a conical nozzle with inserts for Mach 4 and Mach 7 operation, and an instrumentation and data acquisition system. These upgrades configured the tunnel for reflected shock mode operation, resembling the same mode of operation of larger facilities such as T4 [3]. The capability of inexpensively investigating problems of larger facilities such as T4 was made possible with these upgrades.

Further modifications at the end of 1997 and beginning of 1998 improved the performance of the tunnel in a number of ways. The steady test time was increased from approximately 0.4 ms to 1.0 ms by increasing the length of the driver tube from 0.405m to 0.77m. The extra length increases the time before the unsteady expansion reflects off the upstream end of the driver and ends up in the nozzle supply region (see Fig. 1.2). Even though the driver tube length was nearly doubled, the volume of the driver was only increased by approximately 40% to ensure that the absolute pressure in the dump tank does not exceed the atmospheric pressure at anytime during the operation of the facility. The volume constraint was achieved by inserting a polythene sleeve in the lengthened driver.

The capability of double diaphragm operation was removed from the tunnel because of the significant disturbances in the test flow associated with that mode of operation [2].

Single diaphragm operation with synchronized laser firing is made possible in the new modifications through the use of a pneumatic piercer system installed inside the driver. A solenoid valve is electronically actuated releasing regulated bottle pressure to the back of a pneumatic cylinder. This drives a pointed shaft (or piercer) into the primary diaphragm causing it to rupture.

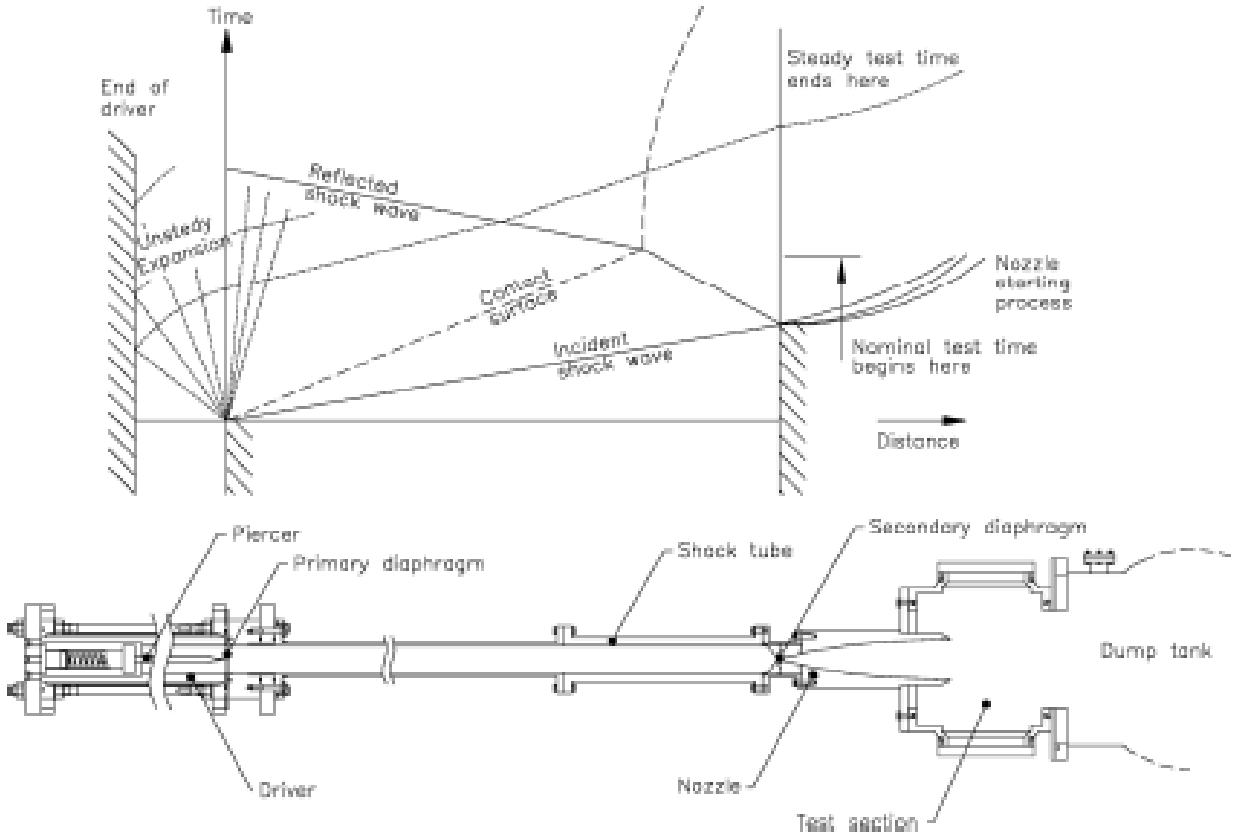

Figure 2: Wave diagram of the shock processes that produce the test flow

A new contoured axisymmetric nozzle was manufactured to produce nominally Mach 7 flowwith minimum flow angularity. A simplex optimization technique was used to optimize designsolutions from parabolized Navier Stokes flow so1ver [4] to generate the design of the contourednozzle. The nozzle was manufactured in three sections using a numerically controlled lathe.

Stainless steel plumbing was also installed for durability and leak prevention. The newplumbing was mounted on a larger control board for ease of operation.

2 Tunnel Operation

The operation of the tunnel essentially consists of evacuating the facility of gas down to approximately 3 torr, filling the shock tube with test gas and the driver tube with driver gas, and then firing the tunnel through the actuation of the diaphragm piercer. Shown in Fig 2.1, is a schematic layout of the plumbing system for the facility. The procedures for safe operation of the tunnel follow.

2.1 Preparation of the facility

Prior to evacuating the facility, all sections must be at atmospheric pressure and the condition of the diaphragms must be ascertained. Follow the list of valve positions in the table below to ensure that the facility is at atmospheric pressure. The valve labels correspond to those shown in *Table 2.1*. Note that the exhaust fan must also be switched on prior to evacuating the facility.

Valve	Position	Purpose
Exhaust fan	Switched on	To direct pump outflow out of lab
Gas Cylinders	Closed	To isolate the gas supply
Regulators	Unwound	Vent residual pressure
V2, P2, P3	Open	To vent the dump tank
V1	Open	To vent the driver
P1	Open	To let dump tank vent through V1
G1, G3, G4, G5	Open	To vent the gauge lines
F1, F2, F3	Open	To vent the fill lines
F4, F5	Open	To vent and retract the plunger

Table 1: Valve positions for evacuating the facility

After the driver and dump tank have completely vented to atmospheric conditions, close the valves P1, P2, P3 and G4. The vacuum pump can then be turned on so that the air valve (AV) may be operated. Ensure that the load valve on the pump is unwound before starting so that undue load is not placed on the pump. After the pump has started up, screw the valve in. The valve AV can now be opened, making it possible to vent the shock tube. AV is opened by closing A1 & A2, and opening A3 & A4 in that order. The shock tube will then vent through the empty fill line via valve F3 & V2.

Once venting is complete, open the primary diaphragm section and check for an intact aluminum diaphragm. If it requires replacing, do so. The rupture pressure of an aluminum diaphragm depends on its grade and thickness. A 0.6mm diaphragm will rupture at either 3.25MPa or 3.4MPa depending on grade. A 0.05mm diaphragm can be made by placing a 0.05mm thick layer of foil on the upstream side of a 0.6mm diaphragm. This ensures that the diaphragm will not rupture at a fill pressure of 3.25MPa (established fill condition for Helium driver and the piercer mechanism can be used reliably. Once the primary diaphragm has been checked, check the secondary diaphragm in the nozzle block. The secondary diaphragm is either cellophane for Mach 4 operation or ”vegetable bag” grade plastic sheet for Mach 7 operation. After reassembling the diaphragm stations, the facility is ready to be evacuated or ”pumped down”.

2.2 Pumping Down

The following procedure isolates the system from the atmosphere and evacuates the driver tube, shock tube, test section and dump tank simultaneously.

Valve	Position	Purpose
Vacuum pump	Turn on	To operate the AV
Load cap	Screw in	Turn knob on vacuum pump clockwise
AV	Open	To open the shock tube to the fill line (see bold above)
F1, F2	Open	To allow fill lines to be evacuated
F4, F5	Open	To evacuate plunger system
G1, G2, G3, G5	Open	To observe the system pressure
F3, V1, V2	Close	Close off the facility from the atmosphere
P1, P2, P3	Open	To open the vacuum lines to the pump
		Pump down the whole system to at least 3 torr (check pressure with G4)

Table 2: Procedure for pumping down the facility

2.3 Filling & Firing

Table 3 is a step-by-step procedure for filling the shock tube and driver sections and firing the shot. Note that AV is closed by closing A3 & A4, and opening A1 & A2 in that order.

Valve	Position	Purpose
F1,F2,F4,F5	Close	To close off the test gas fill & plunger lines
G2,G4	Close	To isolate the vacuum gauges
P1,P2	Close	To stop evacuating the shock and driver tubes
Test gas bottle	Open	
Test gas regulator	Open	Wind down to a pressure $1.5 \times P_{shock}$
F2	Open	To fill the shock tube to the desired pressure Do not fill too rapidly
F2	Close	
G3,G5	Close	To isolate the shock tube gauges and fill lines
P3	Close	To stop evacuating the dump tank
AV	Close	To isolate the shock tube
Driver bottle	Open	
Driver regulator	Open	Wind down to a pressure $1MPa + P_{driver}$ Check oscilloscope & software ready to record
	For operation without piercer	
F1	Open	To fill the driver to rupture pressure Do not fill too rapidly
F1	Close	Note rupture pressure on gauge G1
	For operation with piercer	
Solenoid	Not armed	To ensure piercer does not prematurely actuate Turning switch box off may cause a trigger
F1	Open	To fill the driver (not too rapidly) (Use V1 to vent if driver is overfilled)
F1	Close	
G1	Close	To isolate gauge
F4	Open	To charge the piercer solenoid with driver gas
Solenoid	Armed	
Solenoid	Open briefly	Fire the shot
Driver bottle	Close	
Test gas bottle	Close	
Load cap	Unscrew	Turn knob on vacuum pump anti-clockwise
Vacuum pump	Turn off	So pump does not get loaded when venting
V1,V2	Open	To vent the facility
F1,F2,F3	Open	To vent the facility
P1,P2,P3,G5	Open	To vent the facility
F4,F5	Open	To retract the piercer
Driver regulator	Unwind	
Test gas regulator	Unwind	

Table 3: Procedure for filling and firing the facility

- Once the facility is completely vented, remove the spent primary diaphragm and use the vacuum cleaner to remove any fragments from the driver and shock tube.
- Replace the spent diaphragm, then seal the section.
- Roll the dump tank off the nozzle so that the nozzle block can be removed.
- Replace the spent cellophane/plastic diaphragm and clean out the shock tube and dump tank with the vacuum cleaner.
- Inspect the instrumentation in the dump tank if fitted, ensuring leads are not damaged.
- Replace the nozzle block, then roll the dump tank back into position against the lip of the nozzle.
- The facility is then ready to be pumped down (see Section 2.2).

Drummond Shock Tunnel Schematic

A diagramatic representation of the Drummond Tunnel plumbing is provided below in F*igure3*.

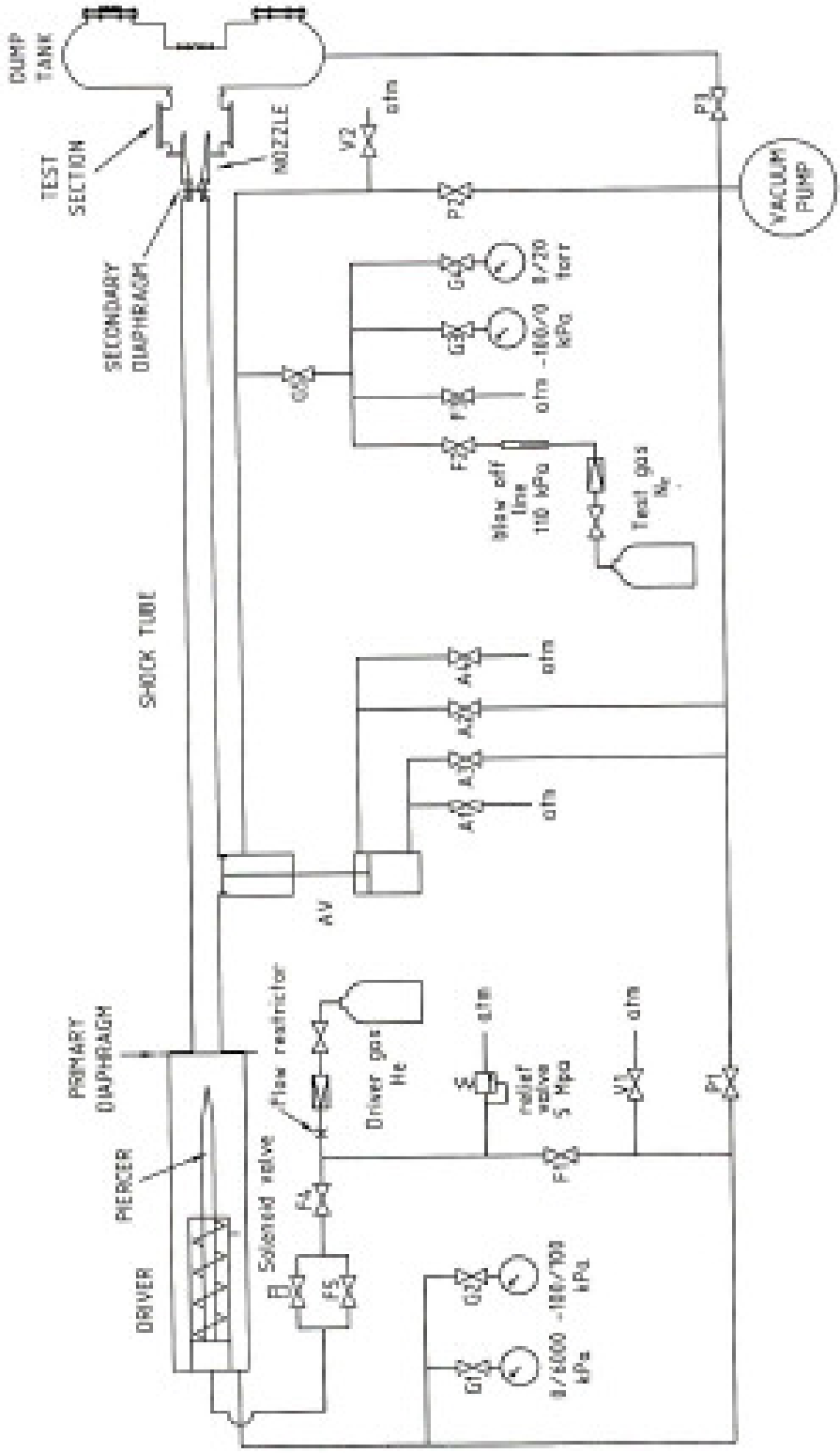

Figure 3: Plumbing for the Drummond Tunnel as of September 2006

References

[1] S. Hiscock, D. Kilpin, and L. Drummond. A Versatile Shock Tube and its Analytical Instrumentation.Technical Report 1819(W), Department of Defence, Salisbury, South Australia, 1977.

[2] J. Austin, P. Jacobs, M. Kong, P. Barker, B. Littleton, and R. Gammie. *The small shock tunnel facility at UQ*. Department of Mechanical Engineering Report 2/97, University of Queensland, 1997.

[3] R. Stalker and R. Morgan. The University of Queensland Free Piston Shock Tunnel T4 – Initial Operation and Preliminary Calibration. *Fourth National Space Engineering Symposium, Adelaide, Australia, IEAust*, 1980.

[4] C. Craddock and P. Jacobs. *A Space-Marching Compressible Flow Solver with Chemistry and Optimization*. Department of Mechanical Engineering Report 698, The University of Queensland, Brisbane, Australia, 1998.